QUALITATIVE AND QUANTITATIVE ASSESSMENT OF TREATMENT DIFFICULTY OF CLASS II PATIENTS

A Thesis

by

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ABSTRACT

The purpose of this study was to determine the physical characteristics and facial types that orthodontists perceive as difficult to treat, and to investigate how their perceptions' relate to the duration of treatment among Class II patients. A survey completed by 122 practicing orthodontists evaluated perceptions of treatment difficulty associated with 16 individual characteristics and 14 facial types, all pertaining to Class II malocclusions. Records of 211 consecutively treated Class II patients ages 10-14 were collected from three private practices. Treatment duration, demographics, pre-treatment cephalograms, and intraoral photographs were evaluated. Orthodontists perceived open bite, impactions, excessive gingival display, and hyperdivergence as the most difficult characteristics to treat, with open bite as the most difficult individual characteristic (8.7 ± 1.6) and facial type component. In the patient sample, open bite, excessive overjet, Class II molar severity, ANB>7°, IMPA>105°, U1-SN, deep bite, the male sex, and Herbst treatment were associated with increased treatment duration, with open bite adding 9.2 months to treatment. Overbite, overjet, U1-SN, sex, treatment start age, and molar Class II explained 23.3% of the variability in treatment duration. This study concluded that open bite is perceived as the most difficult factor to treat and is the most important predictor of increased treatment duration, though excessive overjet and Class II molar severity are also indicative of increased treatment duration. Although orthodontists perceived hyperdivergence and protrusive lower incisors as difficult to treat, neither was strongly associated with treatment duration. U1-SN, however, was

closely associated with treatment duration. Of the factors investigated, overbite, overjet, U1-SN, and molar Class II severity may be the most important components to include in a difficulty index.

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NOMENCLATURE

AAO	American Association of Orthodontics
ABO	American Board of Orthodontics
DI	Discrepancy Index
PAR	Peer Assessment Rating
UTSALD	Upper Tooth size arch length discrepancy
LTSALD	Lower Tooth size arch length discrepancy
MPA	Mandibular Plane Angle
IMPA	Incisor Mandibular Plane Angle
AP	Anteroposterior
SN	Sella to Nasion Plane
U1	Upper Incisor
L1	Lower Incisor
Hyper	Hyperdivergent
Hypo	Hypodivergent

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INTRODUCTION AND LITERATURE REVIEW

Introduction

In orthodontics, many indices exist for classifying pre-treatment malocclusion severity and complexity, and for defining acceptable post-treatment outcomes[1]. Most of these indices were developed to qualify orthodontic cases for government financial aid or to standardize the assessment of treatment,[2] but they have also been used as measures of case difficulty. While case severity and case difficulty are inextricably linked, they are not the same.[3] A patient with a severe skeletal discrepancy may be considered to have a complex malocclusion, while their dental occlusion and treatment objectives render the case easy to treat. On the other hand, a patient with a combination of factors that increase case severity may be difficult to treat due to synergistic effects of different factors. This pertains especially to patients with Class II dental and skeletal malocclusions, who have various treatment options, ranging from growth alteration to extractions or surgery. While a case has been made to utilize severity indices in the judgment of case difficulty, none of the present indices were created specifically for this purpose, possibly failing to incorporate aspects of diagnosis that increase case difficulty.[3]

The goal of this study was to first determine the individual and combinations of diagnostic characteristics that contribute to the orthodontist's perception of case difficulty, and then to test the most agreed-upon characteristics against a retrospective sample of growing patients with a dental Class II malocclusion, treated non-surgically. The focus was on Class II patients to limit the scope of the study. This population also has a vast array of treatment options and diagnostic factors that may increase case difficulty. To assess the perceived factors which contribute to case difficulty, a 15-20-minute survey was distributed to practicing orthodontists in Texas and 1200 members of the American Association of Orthodontics. These responses were then assessed and quantified. This survey included a 0-10 numeric scale scoring system. First, the practitioner scored the difficulty of treating various individual characteristics such as open bite and crowding. Second, the practitioner examined a variety of common Class II facial types, described by horizontal and vertical characteristics such as mandibular plane divergence and incisor proclination, and determine the difficulty of each scenario.[4] The second portion of this study examined the association between orthodontist perceptions of difficulty and actual treatment durations in a patient sample from three orthodontic practices.

One reason for the lack of indices defining case difficulty is the bias associated with the clinician's chosen treatment methodologies and what outcome is deemed acceptable by practitioners[3]. The present study included various treatment methodologies, including headgear, distalization, extractions, Herbst appliances, elastics, and the Forsus Fatigue Resistant Device. Records were collected from consecutive samples of Class II patients aged 10-14. The dental and cephalometric diagnostic characteristics were then compared to treatment duration, which has been previously used as a measure of case difficulty. In the future, a study with specific dental cast measurements will help further elucidate the relationship between diagnosis and treatment duration in the hopes of creating a reliable difficulty index.

An evidence-based index of difficulty could prove to be useful to academic and private-practice orthodontics. In an educational setting, for example, case difficulty indices could be used to equally distribute case-types to residents, and determine which cases may be candidates for treatment by pre-doctoral students. In private-practices, such an index could be used to more accurately determine treatment length and corresponding fees for cases based on difficulty. For orthodontists just beginning their careers, such an index may help more accurately determine treatment difficulty in the absence of experience. A succinct difficulty index, if proven reliable and valid, could be of great use in the orthodontic field.

Literature Review

Orthodontic cases often range greatly in difficulty of treatment. Where one patient may require uncovering an impacted tooth and mini-screw anchorage, another may simply require the alleviation of mild crowding. It makes sense for the treatment expectations and fees for these two cases to differ, yet the modern orthodontist has no objective method to determine the true difficulty of a case, and thus accurately predict the burden of treatment on the doctor’s practice and the patient. While experienced practitioners often have enough anecdotal evidence to accurately predict treatment difficulty, newer orthodontists and residents would benefit from an objective case difficulty index to use as an aid. An objective index for case difficulty, as opposed to case complexity, does not currently exist.[3] Case complexity can be defined as a combination of factors that explain how severely a patient may differ from an ideal dental and skeletal relationship. Case difficulty, while largely related to case complexity or severity, is a measure of difficulty to the orthodontist, resulting in longer treatment times, more chairside and doctor-time, treatment plan changes, and difficulty in accomplishing an acceptable outcome[3]. In particular, no current indices wholly investigate skeletal dental and jaw relationships that can be obtained from a lateral cephalogram, an important diagnostic record routinely utilized by 97% of orthodontists.[7] It is the eventual goal of this study to create an accurate treatment difficulty index that can be used among varying private practices with different treatment techniques and appliances of choice. As a first step, this study will focus on the various Class II cephalometric "types," as described by Moyers, et al, and introduce skeletal and dental cephalometric diagnosis into the assessment of treatment difficulty.[4]

The Importance of Accurate Treatment Difficulty Prediction

Accurate treatment duration prediction and fee schedule planning are vital components to any practicing orthodontist.[8-11] Patients with accurate information are typically more compliant and engaged in treatment, and more satisfied once treatment is completed.[8, 12, 13] Extended treatment times are also associated with harmful side-effects, such as an increased incidence of white spot lesions and increased external root resorption.[14-16] Therefore, an accurate prediction of treatment duration is beneficial in preparing a patient to maintain excellent hygiene throughout treatment and appropriately manage and warn about the risks associated with an extended treatment plan.

Alternatively, an orthodontist may choose to avoid a lengthier plan entirely in a patient who presents with poor oral hygiene or shorter roots during diagnosis.[13] In addition to enhancing clinical care, the ability to accurately predict case difficulty to the orthodontist is important to the financial aspect of treatment. However, even experienced orthodontists tend to significantly underestimate treatment durations.[17] An accurate prediction of treatment duration and potential doctor chairside time based on pre-treatment characteristics can lead to a more appropriate payment schedule that reduces the financial burden of a difficult case on the practitioner and the patient.[10]

Current Indices of Orthodontic Diagnosis

Currently, several indices are being used across various countries to determine government aid for orthodontic patients, quantify treatment outcomes, and distribute cases among new residents[3]. These indices include the Peer Assessment Rating (PAR), the Index of Complexity, Outcome, and Need (ICON), the Index of Treatment Need (IOTN), the American Board of Orthodontics' Discrepancy Index (DI) and Cast-Radiograph Evaluation (CRE), as well as other indices that are not as commonly used. While all of these indices are heavily utilized in determining case complexity, none of them were specifically created to evaluate case difficulty.[3, 18] An index that objectively quantifies case difficulty does not currently exist[3]. Such an index would be a better method for distributing cases among new residents and predicting treatment times than an index of complexity, and may even prove useful for determining if a case is too difficult for treatment by a general dentist as opposed to a specialist.[19] Next, we will explore each of the major existing indices and their relation to case difficulty.

PAR Score

The Peer Assessment Rating (PAR) was one of the initial indices developed for widespread orthodontic use. This index evaluates pre- and post-treatment casts for occlusal changes including the categories of (1) alignment (2) buccal segment relationships (3) overjet (4) overbite and (5) midline discrepancies[20]. Like other indices, the PAR index was validated by weighing the opinion of orthodontists (74 British practitioners in the initial study) with the objective cast measurements mentioned above. Since the original validation, the index has also been validated by practitioners from the United States[20, 21]. This index is thus said to reflect orthodontic professional opinion. The PAR index, like most others, does not incorporate cephalometric data or clinical photos in its diagnosis, and, as such, cannot serve as a tool for ascertaining treatment difficulty, which hinges on soft tissue and skeletal objectives that cannot be gleaned from dental models alone. However, the PAR index does have a correlation with treatment difficulty, because certain aspects of treatment complexity such as overbite, overjet, and maxillary crowding have been associated with statistically longer treatment duration in previous studies[22]. While the severity of dental malocclusion alone does influence case difficulty as measured by duration, the PAR index fails to truly measure case difficulty due to the lack of inclusion of diagnostic tools such as cephalograms.

IOTN (Index of Treatment Need) and AC (Aesthetic Component)

Like the PAR index, the IOTN was developed in Sweden, but is most typically used in Great Britain.[23] The IOTN has two parts: a dental health component and an esthetic component. Dental traits are graded based on treatment need, with a score of 1 indicating no need for treatment and a score of 5 indicating a greater need.[23] The evaluated parameters include crowding, overbite, overjet, an abnormal number of adult teeth, impactions, and soft tissue anomalies as a result of a craniofacial disorder such as cleft lip and palate.[24] Following the dental component, the patient's frontal intraoral photo is matched to one of ten stock photos. Of these photos, four represent no need for treatment on esthetic grounds, three represent borderline cases, and three demonstrate a great need for treatment due to poor esthetics. Clijmans et al. showed that the IOTN does have a significant correlation with the anticipated complexity of treatment as judged by a panel of orthodontists, but only 22% of variability in perceptions of difficulty could be explained by the IOTN[25]. In addition, the dental and esthetic components of this index are often at odds with each other, possibly due to the subjective nature of the esthetic componenet.[26] Because the IOTN is easy to use due to its simple grading system, it is an ideal index for quickly evaluating treatment need, but not treatment difficulty.

ICON (Index of Complexity, Outcome and Need)

The ICON index was original designed as an improvement to the already existing PAR and IOTN indices, seeking to standardize the process of evaluation of pre-treatment and post-treatment casts[26] and create an index that is ideal for simultaneously calculating treatment need, complexity, and outcomes. The developers sought to base this index off of the expert opinion of orthodontic specialists. The index was developed by asking practitioners to look at 240 dental casts, and dichotomously judge a case as needing or not needing treatment and a final result as being acceptable or unacceptable. These practitioners also gave each case a 5-point ordinal score regarding the pretreatment complexity and the post treatment degree of improvement. These scores were based on expert opinion and dental cast evaluations alone. The same dental casts were then evaluated by the developer of the index, taking into account the same dental measurements utilized by the PAR score such as overjet and crowding, and the esthetic portion of the IOTN. The expert opinions were correlated with this objective data. While this index does correlate measurable traits to expert opinion on case complexity, it does not take into account cephalometric values or actually compare the cases deemed "complex" to objective data such as total time in treatment or chairside time. Richmond, et al found that the ICON score had some correlation with perceived treatment difficulty, but not enough to be a strong predictor when correlated with expert orthodontic opinion.[27] In addition, the Aesthetic Component is highly subjective[25]. Therefore, while the ICON index provides a systematic method of determining treatment need or judging treatment outcome based on the opinions of experts, like the PAR index, it is not a valuable index to assess case difficulty objectively.[26]

Discrepancy Index

Of the currently used indices described, only the American Board of Orthodontics' (ABO) Discrepancy Index (DI) utilizes cephalometric values to rate the complexity of a case.[28] The DI was originally created as a means of case selection during board certification in 1998, after five years of scrupulous field testing[29]. This ensured that the cases presented by potential Board-certified orthodontists were complex. Although ABO certification has recently switched to a scenario-based system[30], the discrepancy index remains a beneficial tool in distributing cases of varying difficulties to residents in orthodontic programs, or qualifying a case to be treated at a learning institution at all, where more difficult cases are desirable for learning purposes. The authors of the DI, however, admit that this index was created to ascertain case complexity, which corresponds to a degree with case difficulty, but does not inherently measure case difficulty. Cangialosi et al. stated that, "Difficulty is elusive because inherently it remains somewhat subjective and a matter of perception."[28] This is because some malocclusions that are considered easy to treat by some practitioners may be perceived as difficult to treat by others, and may be reliant on modalities of treatment as well as complexity.[28] Because treatment difficulty is often seen as subjective, we will seek to correlate pre-treatment diagnostic factors with objective data such as treatment duration and doctor chairside time.

Newer Indices

More recently, the Index of Treatment Complexity (IOTC) was developed specifically to measure case complexity and difficulty. The IOTC is based on the PAR index, applying different weights to various components of dental malocclusion[25]. This index does show potential, explaining almost 50% of the variance in treatment complexity when comparing orthodontists' perceived difficulty of treatment and respective IOTC scores, but was least correlated in Class II cases.[31] Newer and lesser known indices have also sought to evaluate treatment difficulty, such as the Korean ICO (The Improvement and Completion of Outcome Index).[32] Unfortunately, like previously described indices, both the IOTC and ICO are only based on cast evaluations. However, an index that was developed by the Indiana University School of Dentistry, called the

Treatment Complexity Index, does evaluate treatment specific treatment modalities used to treat a patient, such as headgear, a fixed functional appliance, extractions, expansion, and surgery. A study by Vu et al. found that this index, as well as DI score to a lesser degree, does correlate to treatment duration.[33]

Previous indices that attempt to correlate treatment difficulty with dental cast evaluations and validate them alongside orthodontists' perceptions have fallen short of a highly linked correlation (R>0.8), perhaps because of the lack of inclusion of cephalograms, which are standard diagnostic records in most practices. Aside from the ABO's Discrepancy Index, which has been self-proclaimed as a measure of complexity rather than difficulty, no other highly utilized index incorporates radiographs into their difficulty assessments[28]. In addition, virtually all indices validate their correlations with perceptions from "experts in the field," or practicing orthodontists from nationally-recognized residency programs. Validation methods do not involve comparing index scores to the objective measures described previously. Thus, no index has been created with the sole purpose of measuring case difficulty. Most correlative studies that came as follow-ups to the development of these indices for treatment complexity found significant but low correlations between index scores and treatment duration.[34]

Objective Measures of Case Difficulty

As previously stated, it is the intent of this study to quantify and validate treatment difficulty with a measure that is objectively linked to difficulty to the orthodontist. In a study by Cassinelli et al., ten orthodontists were asked to select 10 easy and 10 difficult cases from their own treatment pool.[3] The only characteristics which significantly increased the odds ratio of a case being considered difficult were pre-treatment IOTN and PAR scores, as well as the total number of appointments, documented noncompliance, and one-phase treatment plans. Surprisingly, treatment length was not statistically linked to difficulty. However, this study had a small sample size and insufficient power to determine that any one factor was not linked to an increase in case difficulty.[3] While there are few studies that assess the post-treatment quantifiable characteristics that can measure case difficulty, it remains that treatment duration and total appointment time/number directly correlates with the financial burden of treating a patient, and therefore are practical and simple measures that are applicable to private practitioners.

In contrast to Cassinelli's study, a study out of Sweden found a correlation with practitioner-perceived case difficulty and treatment investment.[19] In Bergstrom's study, two orthodontic specialists with over 20 years of experience estimated treatment difficulty for over 300 cases on the basis of pretreatment notes, photographs, and models (excluding cephalograms). These cases were defined as easy, moderately difficult, and difficult. The treatment "investment," a measure that can be compared to treatment difficulty, was then calculated by determining chairside time, treatment duration, and the total number of appointments before debond. Chairside time differed drastically among the differently rated patients, with an average of 100 minutes of chairside time for easy cases, 240 minutes for moderately difficult cases, and 334 minutes for difficult cases. The mean duration of treatment was 15 months for moderately difficult cases, and 24 months for difficult cases. Lastly, the number of attendances for treatment was only 13 for moderately difficult cases, as compared to 23 in difficult cases. While this data may be skewed by the fact that 61% of the cases were treated by general practitioners as opposed to orthodontists, each data point presented was statistically significant.[19] This study shows that treatment duration and chairside time are correlated to perceived treatment difficulty, unlike Cassinelli's study described above.

Richmond, et al. investigated the common denominators in cases found to be difficult by treating orthodontists. In this study, sixteen orthodontists chose 5 completed cases that they deemed to be difficult and 5 that they chose to be easy, and factors that formed a common thread among the 80 difficult and 80 easy cases submitted were statistically analyzed.[27] Poor compliance (58.8%) and poor cooperation (33.8%) were the most common factors in cases considered to be difficult. Increased anchorage requirements (16.3%) and overjet were the next most common factors, indicating that a Class II or Class III relationship may increase the difficulty of a case. In addition, the odds ratio was calculated for a few treatment-related factors. Difficult cases had a significantly higher number of appointments (Odd's Ratio=1.0678) and higher pre-treatment ICON scores (Odd's Ratio=1.0656). This study showed that the most distinguishing factors between easy and difficult cases were the number of appointments and the pre-treatment case complexity, as determined by the initial ICON score. Lastly, statistical analysis showed very similar data for both the UK and Germany, showing that similar factors can render a case difficult even in different countries with potentially different treatment philosophies.[27]

These articles, and those discussed further, show that treatment duration and number of appointments are good, objective measures to determine how difficult a case was in retrospect. This is validated by significant correlations of treatment duration and appointment number to perceived pre- and post-treatment difficulty by the orthodontist, and increased case complexity.[19, 27] The main detriment of using treatment duration as an objective measure of case difficulty is that patient cooperation can extend a treatment plan that would have otherwise been considered easy. However, there is little way to exactly determine a patient's compliance potential prior to treatment, and thus to include it in the prediction of treatment difficulty.

Treatment Duration

Treatment durations among all patients can differ drastically among practitioners and within single practices. Beckwith et al. found that the average treatment time in 5 orthodontic offices was 28.6 months, with a range of 23.4—33.4 months among 140 consecutively treated patients.[9] While overall treatment times vary drastically, the fact remains that certain types of cases take proportionally longer to treat than others.

The total time in treatment varies in particular when comparing Class I and Class II cases, as well as extraction and non-extraction cases. A large-scale study of 567 Class II and 399 Class I patients treated at a university graduate clinic by Vig et al. found that the average duration of treatment for Class I subjects was 24.6 ± 11.6 months and 29.4 ± 11.2 months for Class II subjects, or a difference of approximately five months[35].

O'Brien et al. found that, for growing Angle Class II Division I patients, the average treatment times ranged from 30.6 months on average for extraction cases, to 24.8 months for nonextraction cases.[36] Popowich et al. also found that Class II patients generally take more time than Class I patients, even when comparing nonextraction cases only. He found an average treatment duration of 20.25 months for Class I nonextraction patients, and treatment durations of 25.7 and 24.97 for Class II nonextraction and extraction patients, respectively.[17, 37] He also found that the appliance used can increase treatment duration, with a Herbst requiring 8 months longer in treatment than a headgear.[37] Järvinen at al. also found that Class II Division I cases take longer to treat (3.4 ± 1.3 years) than Class I cases (2.5 ± 1.2 years).[13, 38]

In addition to differences among Class I and Class II malocclusions, the decision to extract also affects treatment duration. Extractions have been found to lead to a longer treatment plan, even when compared among five different private practices, and two-premolar extraction treatments are significantly faster than four-premolar extraction plans.[22, 39, 40] Fink and Smith found an average overall treatment duration for three private practices to be 23.12 ± 6.67 months. Just within one practice, these durations ranged from a low of 19.45 ± 3.52 high of 27.85 ± 4.53, and were even more variable between practices. However, they found four-premolar extraction cases (26.18 months) to take longer than nonextraction cases (21.95 months) in all three of the practices, by about 4-5 months, regardless of the interoffice variability.[11] Another earlier study by Vig et al. of five private practices found a similar relationship: the difference in treatment duration among practices was variable (31.3 months for extraction and 31.2 months for non-extraction cases), but within practices the mean difference between extraction and non-extraction groups could be as high as 7 months[41].

Interestingly, one study that analyzed the characteristics of Class I cases chosen for extraction or non-extraction treatment found that extraction cases tend to have higher overjet and ANB values, indicating that Class II patients may be more likely to be treated with extractions, and, in turn, require a longer treatment duration as demonstrated above.[42]

Factors Associated with Treatment Duration

While it is clear that anteroposterior malocclusion and the decision to extract have a direct impact on treatment duration, there is still variability within these groups. It is of particular interest to this study to determine the specific diagnostic factors that cause variation in treatment duration, and, in turn, treatment difficulty. Various articles show an association between pre-treatment complexities and appointment numbers and treatment duration.[20, 22, 27, 34] While a specific treatment difficulty index does not yet exist[3], several studies have sought to correlate specific aspects of treatment with treatment duration. In fact, pre-treatment PAR, ICON, and DI scores have been shown to account for up to 30% of the variability in treatment duration.[20, 22, 27, 33, 34]

Various aspects of treatment complexity have been found to be significantly associated with treatment duration. In a systematic review published in the European Journal of Orthodontics in 2008, it was concluded that extraction treatment, two-phase treatment, and impacted maxillary canines significantly increase treatment duration.[13] The systematic review also found that, while severity of the initial malocclusion may play a role in treatment duration, there is not enough data to draw definitive conclusions about the role of various discrepancies, and more studies are required for conclusive data.[13] Daniels and Richmond found a correlation between treatment duration and extractions, broken appointments, ANB angle, Salzmann Index, and mandibular plane angle (MPA). Increases in ANB and the Salzmann Index (a methodology for evaluating dental casts that is similar to the PAR), and decreases in the MPA led to an increased treatment time.[26]

In 2011, Parrish, et al. published a study that tested the relationship between the American Board of Orthodontics' Discrepancy Index (DI) and treatment duration in a graduate orthodontic clinic.[34] This study found a significant association between DI score and treatment duration, with a multivariate association between specific variables such as occlusion, crowding, overjet, cephalometric measurements, overbite, and tooth transpositions.[34] While the DI score and its components were significantly correlated to treatment duration, this correlation was low (95% CI: 0.23 to 0.36).[34] In addition, this paper did not analyze if a specific combination of factors were associated with increased treatment duration. Lastly, this study included a patient sample from a residency program, and, as such, is not as applicable to a private practice population due to iatrogenic errors resulting from inexperience, various instructors with different mechanisms of treatment, and the possibility of resident transfers which increase the treatment time for most cases based out of a teaching institution.[34] However, this study does show that pre-treatment complexity, and especially cephalometric factors, can be somewhat predictive of treatment duration and difficulty.

Factors that are difficult to predict from an initial exam have also been implicated in determining treatment duration. These factors include noncompliance, broken appointments, and broken appliances. One study analyzing the difference in treatment duration in adults and adolescents found that the number of broken appointments and appliance repairs explained 46% of the variability of orthodontic treatment duration, while the pre-treatment PAR score only explained 14% of this variability. There was no difference in treatment duration for adolescents and adults in this specific study.[43] Another study corroborated the finding that poor patient compliance led to an increased treatment duration.[44] While the effect of noncompliance and failed appointments is unquestionable[41], this is not objectively predictable at the beginning of treatment. Additionally, in a study by Haralabakis and Tsiliagkou, noncompliance and broken appointments were used as exclusion factors, and factors such as age, molar relationship, extractions, and pre-treatment PAR scores still explained 46.33% of the variability in treatment duration.[45]

Though there have been several studies attempting to link pre-treatment factors with treatment duration, most have had variable results. While patient compliance cannot be accurately predicted before treatment is initiated and a price point is set, pre-treatment diagnostic characteristics may be more practical predictors of increased treatment duration. The significant correlation between various pre-treatment factors and treatment duration is promising in the creation of a difficulty index. These correlations prove that pre-treatment factors, while not all-encompassing, can help predict difficult cases with some degree of accuracy.

Treatment Duration in Class II Patients

This study seeks to focus on Class II dental malocclusions and correlate various skeletal and dental patterns with both practitioner perceptions of difficulty and actual treatment durations, with the hope of eventually creating a valid index for predicting treatment difficulty. Aside from creating a more specific initial study, part of the reason for focusing on Class II malocclusions is the variability in treatment times for these patients as influenced by the chosen treatment modality, which is, in turn, determined by the specific patient malocclusion and skeletal pattern.[17] Although the DI index does include cephalometric measurements in its analysis, it is difficult to determine how much of treatment duration is affected by cephalometrics and skeletal patterns alone.[34] Skeletal and dental diagnostic measurements gleaned from cephalometric radiographs, and especially combinations of these measurements, have rarely been analyzed in terms of treatment difficulty in the literature.

Dental diagnostic measurements and treatment modalities have been associated with treatment duration in many studies on Class II malocclusions, as well as noncompliance. Both Kim et al. and O'Brien et al. determined that Class II treatment length is affected significantly by pre-PAR score.[36, 46] O'Brien's study also found that compliance in terms of the appointments attended, the number of appliances used, the number of phases of treatment, and the decision to extract also affect treatment duration in Class II patients.[36] Yet another study by Skidmore et al., found that a Class II molar relationship does significantly impact treatment duration, as well as extraction treatment plans, maxillary crowding greater than 3 mm, being male, and poor patient cooperation[47].

In terms of treatment modalities, a study by Popowich et al. found that Herbst appliance treatment took significantly longer than similar cases treated with headgears (8 months), while a study by Beckwith et al., found that headgear increases the length of treatment over cases in which Class II correction is not required.[9, 17] Yet another study found that, when treated with fixed functional appliances, treatment duration is most significantly correlated to the resulting changes in incisor angulation, and not skeletal measures such as SNA, SNB, and ANB.[48] These sporadic results demonstrate the variability in treatment duration depending on the modality of treatment chosen, as well as the variability of studies done on this topic. Overall, most studies do find that the severity of various dental, skeletal, and treatment-related factors in Class II patients have a significant influence on treatment duration.[17, 36, 46]

Cephalometric Analysis as a Predictor of Treatment Duration in Class II Patients

Cephalometric analysis is of particular interest in growing patients with a Class II malocclusion because of the variety of treatment modalities available to modify Class II growth, and the role which cephalometrics can play in the treatment decision. For example, the pattern of growth, such as a hyperdivergent tendency, may preclude a patient from treatment with a specific orthopedic device, such as the negative effects of Herbst treatment on a patient with a hyperdivergent mandible.[49]

In a study by Kim et. al, cephalometric variables were tested as predictors of Class II treatment outcomes. Pre-treatment complexity was determined with a PAR score, and treatment outcomes were assessed by determining post-treatment PAR, relative PAR reduction, and treatment duration. Cephalometric variables involved 41 typically-used measurements, including the ANB angle, mandibular plane angle, anteroposterior positions of the jaws, and protrusion of the incisors. In this study, the cephalometric parameters analyzed explained almost 40% of pre-treatment malocclusion severity and 20% of treatment duration variance. However, this study did not account for potential non-linear relationships between cephalometric measures and treatment duration, nor the effect of interactions among cephalometric variables. In addition, an overjet of 5 mm was an inclusion criteria for the study, eliminating variability among many patients who had a Class II Division II malocclusion.[46]

Nonetheless, studies such as this show that cephalometrics and, in turn, skeletal parameters do correlate with treatment complexity and treatment difficulty. The study by Popowich et al. showed a significant correlation with pre-treatment ANB and treatment duration, while Fink and Smith showed an association with treatment duration, pre-treatment ANB, and mandibular plane angle.[11, 37] A study by Andria et al. correlated cephalometric cranial base measurements with treatment timing, determining that that the saddle angle (Basion—Sella—Nasion) does not correlate to treatment timing. In contrast, this study did show that a longer posterior cranial base length (Basion—Sella) has a negative correlation to treatment time. This is of particular interest because a shortened posterior cranial base can indicate a more vertical mandibular growth pattern and angulation, implying that hyperdivergence may take longer to treat than individuals with shallower mandibular plane angles.[50] There are few other studies analyzing the effect of cephalometric analysis on treatment duration in Class II patients.

Class II Skeletal Types

While studies that correlate specific skeletal and dental factors with treatment duration do exist, no study takes into account combinations of cephalometric factors that lead to a global diagnosis and eventual treatment plan for most patients. It is the goal of this study to evaluate specific combinations of skeletal and dental factors in Class II patients to evaluate a more explanatory method of determining treatment difficulty.

An Angle Class II malocclusion is defined by Edward Angle as the mandibular teeth occluding distally to the maxillary teeth, by one or more bicuspid width.[51] In his classic 1980 paper, Robert Moyers developed a list of facial types associated with Class II dental malocclusions. In his study, Moyers evaluated 697 North American white children who had undergone treatment by an orthodontist for their Class II dental malocclusion. Moyers included 57 untreated children with Class II dental malocclusions from the Michigan Growth Study as well. These types involve various combinations of anteroposterior and vertical skeletal and dental positions. The variations of skeletal Class II's include the following anteroposterior and vertical types:

Horizontal Types	**Vertical Types**
Type A: Normal skeletal profile with a normal occlusal plane and anteroposterior position of the mandible (Class I skeletal bases), with a large overjet and deep bite, accompanied by maxillary incisor protrusion.	Type 1: Steep mandibular plane and occlusal planes, and a tipped down palate, causing a "long face" appearance.
Type B: Class II skeletal profile due to a midface prominence and upper incisor proclination, with a normal-sized mandible.	Type 2: A square face with flat mandibular, occlusal, and palatal planes, with a vertical incisor position and a deep-bite.

Type C: Class II skeletal profile due to smaller facial dimensions with a retrusive maxilla and further retrusive mandible, accompanied by proclined lower incisors and proclined or upright upper incisors.	Type 3: An upwardly tipped palatal plane with an open bite and a hyperdivergent mandibular plane.
Type D: Class II retrognathic profile due to a small mandible and a normal or slightly small midface, with upright or retroclined lower incisors and labially inclined upper incisors.	Type 4: The mandibular, occlusal, and palatal planes are all tipped markedly down with vertical maxillary excess and often have upper incisor protrusion and lower incisor retroclination.
Type E: Class II profile due to a prominent midface and normal mandible, with a tendency for the upper and lower incisors to be strongly proclined. This skeletal type often accompanies bimaxillary protrusion.	Type 5: Similar to type 2, but with a more severe skeletal deep-bite with the lower incisors in extreme labioversion and the maxillary incisors retroclined. Can also appear as bimaxillary protrusive.

This study will focus on the specific anteroposterior and vertical combinations of skeletal Class II patterns as described in the Moyers study, which found 16 total combinations or “types” in the patient sample described. It is the hypothesis of this paper that, in combination, the skeletal and dental factors described have a significant effect on total treatment time for Class II patients. The treatment time for each of these various types, as well as a survey denoting the opinions of practicing orthodontists, will be assessed in relation to actual treatment times from three private practice orthodontic offices. It is the eventual goal of this pilot study to create a difficulty index which can help determine treatment duration and, in turn, treatment difficulty, for Class II patients.

CHAPTER II

MATERIALS AND METHODS

This project includes a survey portion and a private practice portion. IRB approval (IRB ID: 2017-0946-CD-EXM) was granted for both portions.

Part 1: Survey Portion

The survey portion of this project was designed to evaluate orthodontists' perceptions of case difficulty (Addendum 1)

Survey Conception

The purpose of the first part of this study was designed to determine practicing orthodontists' perceptions of case difficulty when treating growing patients with a Class II dental malocclusion.

The survey included three sections: the first section assessed the difficulty attributed to individual diagnostic factors, the second section assessed combinations of skeletal and dental factors used to classify horizontal and vertical Class II types,[4] and the third section was demographic. Respondents were asked to rank the difficulty of diagnostic factors and scenarios using a numerical rating scale, a type of visual analog sliding (VAS) scale. The scale ranged from 0 to 10, with 0 indicating no treatment difficulty and 10 indicating a very high treatment difficulty. Numerical rating scales are reliable and valid survey methods, both electronically and in paper form, where the responses can be analyzed as continuous level variables.[52-54]

The first part of the survey asked respondents to determine the difficulty of treatment posed by sixteen dental and skeletal factors, including, among others, deep bite, open bite, impactions, habits, and crowding (Figure 1). These factors were derived from the ABO's Discrepancy Index[28] and from expert opinion (full-time orthodontic faculty at Texas A&M University College of Dentistry).

In the second part of the survey, the most common combinations of 5 vertical and 5 horizontal skeletal facial types were used to create 14 facial types (Table 2).[4] Each facial type includes different anteroposterior positions of the maxilla and mandible (retrusive, normal, or protrusive), different anteroposterior inclinations of the upper and lower incisors (retrusive, normal, or protrusive), different anteroposterior relationships between the maxilla and mandible (Class I or Class II skeletal), different mandibular plane angles (hyperdivergent, normodivergent, or hypodivergent), and differences in overbite (deep bite, normal bite, or open bite). Each facial type also included a lateral cephalogram for a visual aid. The respondents were asked to use a slider to rate the difficulty of treating each of the fourteen cases on a scale from 0 to 10.

The third part of the survey provided demographic information, including sex, years in practice, and ABO certification status.

Survey Distribution

A paper version of the survey was distributed to practicing orthodontists at the Texas Orthodontic Study Club Meeting in Houston, Texas in January, 2018. Qualtrics was used to create an identical electronic version of the survey. The AAO Partners in Research program then distributed the electronic version to a random sample of 1200 members who were practicing orthodontists on March 24, 2018. A reminder to respond was sent two weeks later. Of the 1200 AAO members to whom the survey was distributed, 105 responded, indicating a response rate of 8.8%. Of the 30 paper surveys that were distributed, there were 17 responses collected, indicating a response rate of 56.7%. Combining the electronic and paper surveys, the overall response rate was 9.9%.

Part II: Private Practice Portion

The second portion of this project involved collecting data from three private practices in Texas, labeled A, B, and C. The same investigator performed all of the data collection. At each of these practices, data was collected based on consecutively treated patients over the past 10 years, resulting in 92 patients from Practice A, 69 from Practice B, and 50 from Practice C. These patients met the following criteria:

Inclusion Criteria:

- Completed cases treated by the private practitioner from beginning to end (no transfers).
- At least a ½-step Class II unilateral molar relationship, or a ¼-step Class II bilateral molar relationship (a molar sum of 2, with 1 point assigned for each ¼ step of Class II for each molar [Table 1]).[55]
- Growing patients ages 10-14
- Pre-treatment diagnostic records as follows:
    - Lateral cephalogram or CBCT
    - Panoramic X-ray

    - Intraoral Photographs
    - Clinical exam notes
- Treatment notes, including the number of emergencies, the bonding date or initial appliance placement date, and the debond date.

Exclusion Criteria:

- Documented early debonds
- Hypodontia (excluding third molars)
- Surgical treatment plans

Ten landmarks (Figure 1) were digitized on pre-treatment cephalometric radiographs based on standardized definitions:[56]

- Sella (S)—the center of the pituitary fossa
- Nasion (N)—the most anterior point of the frontonasal suture
- A-point (A)—the most posterior point in the concavity between ANS (anterior nasal spine) and the maxillary alveolar process
- B-point (B)—most posterior point in the concavity between the chin and the mandibular process.
- Upper incisor edge tip (U1-E)—tip of the incisal edge of the maxillary central incisor
- Upper incisor root apex (U1-A)—tip of the root apex of the maxillary central incisor
- Lower incisor tip (L1-E)—tip of the incisal edge of the mandibular central incisor
- Lower incisor root apex (L1-A)—tip of the root apex of the mandibular central incisor

- Menton (Me)—The most inferior point of the mandibular symphysis
- Gonion (Go)—The point on the curvature of the mandible located by bisecting the angle formed by the lines tangent to the posterior ramus and the inferior border of the mandible.

Five angular measurements were computed for the analysis[57]. Linear measurements were not used because some of the cephalograms in the study did not include calibration rulers.

- SNA—the angle formed by the intersection of the lines between Sella and Nasion and Nasion and A-point
- SNB—the angle formed by the intersection of the lines between S and N and N and B-point
- U1-SN—the angle formed by the intersection of the lines between Sella and Nasion and the maxillary central incisor's incisal edge and root apex.
- IMPA—the angle formed by the intersection of the lines between Gonion and Menton and the mandibular central incisor's incisal edge and root apex.
- MPA——the angle formed by the intersection of the lines between Sella and Nasion and Gonion and Menton.

The ANB, U1-SN, IMPA, and MPA were divided into two categories based on a cutoff value. An ANB of <4° was indicative of a Class I skeletal relationship, while an ANB of ≥4° was considered a Class II skeletal relationship.[58, 59] An additional ANB analysis was done with a cutoff point of 7°. For U1-SN, 100-110° was used as the range for a normal angulation because these values are one standard deviation above and below the normative values for 10-14 year-olds, with <100° considered retrusive and >110° considered protrusive for the purposes of this study.[60] Similarly, for MPA, 28-38° was used as the range for a normal angulation because these values are one standard deviation above and below the normative values for 10-14 year-olds, with <28° considered hypodivergent and >38° considered hyperdivergent for the purposes of this study.[60] A protrusive IMPA was considered to be above 100°, mimicking the ABO's Discrepancy Index.[28] Again, there were too few cases with retroclined lower incisors to include a lower cutoff point. An additional IMPA analysis was done with a cutoff point of 105°. Overbite was divided into normal, deep, and open bite groups. Overjet was classified as normal (normal to mild overjet) or excessive (moderate to severe overjet). Lastly, each patient's treatment record was assessed to determine sex, date of birth, date of treatment start and completion, and the mode of treatment and Class II correction. The treatment start date was defined as the first day of bonding or banding for an appliance for comprehensive orthodontic treatment.

The molar relationships (Table 1), tooth size arch length discrepancies, overjet, and overbite were estimated from the intraoral photos and cephalograms. Each of the first three attributes were categorized by the investigator as either normal to mild, moderate, or severe. Overbite was categorized as deep, normal, or open. Replicate analysis of thirty randomly selected patients was performed one month after initial data analysis. The method error ranged from 0.07 to 0.56, with a method error of 0.07 for right and left molar classification and a method error of 0.56 for IMPA.

Statistical Analysis

All of the cephalometric tracings were completed before assessing the intraoral photographs. The demographic and treatment record data were collected last. Once all data were collected, they were coded and entered into SPSS Version 25 (IBM SPSS Statistics Inc., Chicago, IL) for statistical testing. Significance level was set at 0.05. All of the continuous data were determined to be normally distributed.

Data from the first section of the survey was ranked by difficulty score, and sorted into tiers. The tiers were ranked in descending order of difficulty and evaluated using paired t-tests. An asterisk distinguished the "Open Bite" category from the other tiers, which were designated with brackets (Figure 2). Paired t-tests were also used to compare data from the second section of the survey, with brackets and an asterisk indicating significantly different tiers of difficulty (Figure 3).

In addition, data from the second section of the survey was regrouped to determine the contribution of the individual factors that made up the 14 facial types (Table 3). The difficulty ranking for each individual factor was calculated by averaging the scores for the facial types that included that factor (e.g. there were seven facial types that involved protrusive lower incisors). These data were analyzed for differences using the Kruskal-Wallis ANOVA one-way analysis of difficulty followed by a post-hoc Bonferroni test.

For the private practice data, a ANOVA one-way analysis followed by a post-hoc Bonferroni test was used to determine any significant differences in treatment start age, treatment duration, emergencies, cephalometric data, and molar classification among the three practices (Table 4). The nominal data from the private practices was described using frequencies, and a Chi-square test followed by a post-hoc Bonferroni test were used to determine whether there were significant differences related to the distribution of sex, overbite, overjet, maxillary and mandibular TSALD, or treatment type among the three practices (Table 5). The grouped subsets from the private practices were compared using independent t-tests (Table 6).

Treatment duration differences between different treatment types were analyzed using one-way ANOVA followed by a post-hoc Bonferroni test (Table 7). The elastics and Forsus groups did not have significantly different treatment durations, so they were combined for analysis. This data was then sorted into normal overjet (normal to mild) and excessive overjet (moderate to severe) groups for additional analysis.

Lastly, Pearson bivariate correlations were used to determine the correlation between treatment duration and the continuous data collected from the private practices (Table 8).

CHAPTER III

RESULTS

Survey Demographics

Of the respondents who disclosed their sex, 86 were male (82.7% of the total) and 18 were female (17.3% of the total). The average reported years in practice was 18.6 ± 11.0 years. Of those who disclosed their ABO certification status, 48 (45.3%) were ABO certified and 58 (54.7%) were not. While sex had no significant effect on the responses for any portion of the survey, ABO certification status and years in practice did significantly influence difficulty rankings. There was no significant difference in reported years of experience between ABO-certified (18.9 ± 8.9 years) and non-certified orthodontists (18.3 ± 12.4 years).

In the first section of the survey, ABO-certified orthodontists ranked protrusive lips and dental crossbite as significantly easier to treat than non-certified orthodontists. In contrast, they reported bimaxillary retrusion as significantly more difficult to treat.

In the second section of the survey, ABO-certified orthodontists ranked facial types 1 (Class II, normal maxilla and retrusive mandible, hyperdivergent, normal overbite and normal incisor proclination), 12 (Class II, retrusive maxilla and mandible, hyperdivergent, open bite, and protrusive incisors) , and 13 (Class II, normal maxilla and retrusive mandible, hyperdivergent, open bite, and normally inclined upper and lower incisors) as significantly easier to treat than non-certified orthodontists.

Based on the Spearman correlations, the difficulty score for severe crowding (R=0.211), severe spacing (R=0.253), protrusive lips (R=0.224), excessive gingival display (R=0.276), and deficient gingival display (R=0.362) were all significantly and positively correlated with years in practice. The facial type rankings in the second section of the survey were not significantly correlated with practice experience.

Survey Section I

Open bites were perceived to be significantly more difficult to treat than any of the other individual factors (Figure 2). The next tier of difficulty included impactions (6.8 ± 2.1) and excessive gingival display (6.7 ± 2.3). These factors' difficulties were all ranked significantly lower than open bite, but also significantly higher than the next tier of factors, which included parafunctional habits, protrusive lower incisors, and bimaxillary retrusion, which were perceived to be significantly more difficult to treat than skeletal crossbite, retrusive lips, deep bite, and crowding. The least difficult factors to treat were protrusive lips (3.6 ± 2), dental crossbite (3.6 ± 2), and protrusive upper incisors (3.2 ± 2).

Survey Section II

Facial types 12, 13, and 5 comprised the top tier of difficulty (Figure 3). Each of the facial types included hyperdivergence and open bites. Facial type 10, which also involved hyperdivergence and open bites, but with retrusive lower incisors, represented the next tier of difficulty. There were four additional tiers of difficulty. Facial types with hypodivergence, deep bites, and normally inclined lower incisors (facial types 8, 9, and 2) was the tier perceived to be the least difficult to treat.

When the factors included in the facial types were evaluated separately, hyperdivergence, open bites, and retrusive lower incisors showed the highest difficulty scores (Table 3). However, some of the factors were not evenly distributed among all of the facial types. For example, retrusive lower incisors were only associated with facial type 10, which also involved hyperdivergence and open bite, both of which were major contributors to treatment difficulty. This inflated the treatment difficulty score of retrusive lower incisors (Table 3). For the same reason, treatment difficult was also inflated for a retrusive maxilla.

When facial types were grouped based on having an open bite (types 5, 10, 12, and 13), a normal bite (types 1 and 11), or a deep bite (types 2, 3, 4, 6, 8, and 9), open bites were deemed to be significantly more difficult to treat than normal overbites, which were significantly more difficult to treat than deep bites (Table 3). In addition, when facial types were grouped based on being hyperdivergent (facial types 1, 5, 10, 11, 12 and 13), normodivergent (facial types 3 and 6), and hypodivergent (facial types 2, 4, 7, 8, 9, and 14), the hyperdivergent facial types were deemed to be significantly more difficult to treat than normodivergent and hypodivergent types, which were not significantly different from each other.

Private Practice Comparisons

The mean treatment start age did not differ significantly among the three practices (Table 4). However, there were other significant between-practice differences. These include a significantly shorter treatment duration in practice C than practices A and B, significantly more emergencies per patient in practice B than practices A and C, a significantly higher mean SNA in practice A than practice B, a significantly lower mean IMPA in practice B than practices A and C, and a significantly lower combined molar sum in practice C than practices A and B (Table 4).

In addition, practice C had a higher proportion of cases with normal overbites, normal overjets, and insignificant TSALDs than practices A and B, indicating a less complex patient population (Table 5). Practice A prescribed 1-4 extractions in 48.8% of cases, practice B prescribed extractions in 21.7% of cases, and practice C prescribed no extractions. All of the practices prescribed a Herbst appliance for over a third of their patients, while headgear and distalization were rarely used. Elastics or the Forsus Fatigue Resistant Device (3M Unitek Corp, Morovia, Calif.) was utilized in 11.0% of cases for practice A, 33.3% of cases for practice B, and 54.0% of cases for practice C (Table 5).

Private Practice Subset Comparisons

ANB, U1-SN, IMPA, overbite, overjet, and sex subsets showed statistically significant differences in treatment duration (Table 6). While there were no statistically significant differences when the ANB cutoff point was set at 4°, when this cutoff was changed to 7°, patients with an ANB of ≥7° took 3.3 months longer to treat than those with an ANB of <7°. Patients with a protrusive U1-SN took 4.9 months longer to treat than those with a normal U1-SN. There was no significant difference in treatment time between patients with a normal and retrusive U1-SN. While IMPA showed no difference with a 100° cutoff point, there was a significant, 4.2-month difference in treatment duration between groups when the IMPA cutoff was changed to 105°. There was no significant difference in treatment duration among hypodivergent, normodivergent, or hyperdivergent patients. Patients with an open bite took 9.2 months longer to treat than those with a normal overbite and patients with a deep bite took 4.1 months longer to treat than those with a normal overbite. Those with excessive overjet (moderate to severe) took 4.3 months longer to treat than those with normal overjet. Finally, males took 3.6 months longer to treat than females.

Overall, patients treated with a Herbst appliance took 4.2 months longer to treat than those treated with extractions, and 6.9 months longer to treat than the elastics/Forsus group. These groups were further divided into patients with normal and excessive overjet (Table 7). For patients with normal overjet, treatment with a Herbst appliance took 5 months longer than treatment with extractions and 7.2 months longer than treatment with elastics/Forsus. For patients with excessive overjet, there was no significant difference in treatment duration between any of the treatment modalities.

Private Practice Relationships

The relationship between treatment duration and the other variables collected in the private practices showed only a limited number of associations (Table 8). Start age, U1-SN, and molar sum were all significantly correlated with treatment duration. Treatment duration was positively related to U1-SN and molar sum, indicating that patients with more protrusive upper incisors or greater Class II molar relationships took longer to treat. Treatment duration was negatively related to the patient's age at the beginning of treatment, indicating that younger patients took longer to treat. A multiple regression analysis involving all diagnostic criteria showed that overbite, overjet, U1-

SN, molar sum, sex, and treatment start age together explained 23.3% of the variability in treatment duration ($R=0.504$, $p<0.001$), while overbite, overjet, U1-SN, and molar sum alone explained 20.1% of the variability in treatment duration ($R=0.448$, $p<0.001$)

CHAPTER IV

DISCUSSION

The survey response rate in the present study falls within the range reported in the orthodontic literature. The overall response rate was 9.9%. Response rates of AAO members have been reported to range from 6% to 39%.[61-63] For example, Buschang et al reported a response rate of 6% to a 28-question survey distributed to 9,470 AAO members regarding miniscrew implants.[61] The complex nature of the survey used in the present study, requiring about 15-20 minutes to complete, may have discouraged some practitioners from responding.

Importantly, the survey respondents in the present study were representative of the general population of orthodontists. Of the respondents, 17.3% were female, the average years in practice was 18.6 years, and 45.3% were ABO-certified. These demographics correspond closely to the JCO’s 2017 Practice Study, which found that women make up 19% of practitioners and the average experience level for a practicing orthodontist is 20 years.[64] In addition, the ABO reports that approximately 44% of AAO members are board-certified.[65]

Years of experience affects orthodontists’ perceptions of treatment difficulty. In the present study, those with greater experience rated severe crowding, protrusive lips, gummy smile, deficient gingival display, and severe spacing as more difficult to treat. These associations may be related to differences in treatment plan choices between experienced and inexperienced practitioners. In particular, crowding, protrusiveness, and deficient gingival display are more likely to require extractions, which experienced practitioners may realize will add time to treatment.[66, 67] Practitioner experience is the only factor that has previously been correlated with differences in treatment plans among orthodontists.[68] It has been shown that orthodontists with 15 years of experience are significantly more likely to prescribe extractions in borderline cases than those with less than 5 years of experience.[63] If treatment difficulty is affected by experience, any future difficulty index should strive to help new, inexperienced orthodontists distinguish the factors that result in a lengthier treatment time.

ABO-certification also affects the perception of difficulty among practitioners. ABO-certified orthodontists perceived protrusive lips, dental crossbites, and facial types 1, 12, and 13 (all involving hyperdivergence and a retrusive mandible) as significantly easier to treat than non-certified orthodontists, and bimaxillary retrusion as significantly more difficult to treat. These differences were not related to differences in experience, as there was no significant difference in years in practice between the two groups. They may be related to the fact that ABO-certified orthodontists have been forced to thoroughly reflect upon their own cases (prior to the implementation of the scenario-based ABO exam), and therefore may have different opinions of what individual factors contribute to case difficulty. Board-certified orthodontists may also be more critical in their evaluation of cases post-treatment, making them more aware of these associations.

Open bites are among the most difficult malocclusions to treat. In the survey, an open bite was ranked as significantly more difficult to treat than any other individual factor. It also was the highest ranked individual component of the facial types, making up the top two tiers of difficulty. In the private practice population studied, open bite patients took 9.2 months longer to treat than patients with a normal overbite, and 4.1 months longer than patients with a deep bite. No study has previously evaluated the effect of open bite on treatment time. Previous studies evaluating overbite (i.e. both open and deep bite) have shown both associations[27, 69] and no association with treatment duration.[41] Studies have also found positive correlations between treatment duration and various occlusal indices (e.g. PAR and ICON) that include overbite as a scoring parameter.[20, 21, 25, 27, 70] The difficulty of treating open bites could partially explain why these indices are correlated to treatment duration.[71] Due to the many etiologies of open bite, treatment may include extractions,[43] a habit appliance, myofunctional therapy,[72, 73] molar intrusion, orthopedic correction,[74] or extensive elastic use,[71] which all require optimum compliance. Therefore patients with open bites are likely to have extended treatment durations because additional steps and compliance are almost always required to resolve the problem. [71]

According to the orthodontists' perceptions and the private practice data, deep bites contribute moderately to treatment difficulty. In the first section of the survey, deep bites were ranked in the middle tier of difficulty, and were considered easier to treat than both open bites and normal bites in the second section of the survey. In the private practice sample, deep bites added 4.1 months to treatment compared to normal overbites. Most studies have found a positive association between deep bite and treatment duration,[22, 34, 47] although one reported no association.[43] Deep bites may take less time to treat because they are often accompanied by hypodivergence and favorable growth patterns, aiding in Class II correction.[75] However, the actual contribution of deep bites to treatment duration is likely related to the extra time needed to level the Curve of Spee.[22] While deep bites are not as strongly related to orthodontist perception of difficulty as open bites, they still contribute significantly to treatment duration.

Despite the association of overbite with treatment difficulty, mandibular plane angle does not appear to affect treatment duration, contrary to the orthodontists' perceptions. In the private practice sample, there were no significant differences in treatment duration between hyper-, hypo-, and normodivergent patients, nor was MPA significantly correlated with treatment duration. The MPA has been implicated as a possible, but clinically insignificant, contributor to treatment duration.[34, 46] Two studies found an association with increased treatment duration and hypodivergence,[11,22] while another found no association between gonial angle (correlated to MPA)[76, 77] and treatment duration.[9] While hyperdivergent patients often exhibit backward rotation of the mandible with growth, which is detrimental to Class II correction,[78] hyperdivergent patients have also been shown to exhibit lower bone density than hypodivergent patients due to lower bite forces,[79-81] and faster tooth movements.[82] Thus, if appropriate mechanics are used, hyperdivergent patients may overcome the potentially detrimental effect of backward mandibular rotation because their teeth simply move faster.

Interestingly, orthodontists perceive hyperdivergence as being more difficult to treat than hypodivergence, which is at odds with the private practice sample. Hyperdivergence ranked third in terms of contribution to facial type difficulty, creating a disparity between orthodontist perception and the negligible effect of MPA on treatment duration. This discrepancy could be explained by the association of hyperdivergence with a skeletal open bite in the survey, rather than hyperdivergence alone. Of the six hyperdivergent facial types, the two lowest ranked (types 1 and 11) were not associated with an open bite. In the survey, four of the six hyperdivergent facial types had open bites (66.6%), while, in the private practice population, only one of the 39 hyperdivergent patients (MPA>38°) had an open bite (2.6%), and only one of the six open bite patients was hyperdivergent (16.7%). Open bite malocclusions are actually more likely to be associated with normo- or hypodivergence than hyperdivergence.[83] Therefore, it is likely that practitioners associate a skeletal open bite with difficulty, as opposed to hyperdivergence alone.

Orthodontists perceived impactions as one of the most difficult problems to treat. In the first section of the survey, impactions had a mean difficulty score of 6.8 ± 2.1. Bringing impacted canines into the arch has been shown to add 3-6 months to treatment,[11, 84] likely because the canines must be brought into place before alignment can be completed. In addition, impactions, which are scored as part of the PAR index, the Discrepancy Index, and newer indices, help to explain the association of these indices with treatment duration.[28, 32, 55].

The degree of the Class II malocclusion is also related to increased treatment time. In the present study, patients with excessive overjet (moderate to severe) took 4.3 months longer to treat than those with normal overjet (normal to mild). The patients' molar sums and overjets were positively correlated with treatment duration. Excessive overjet and buccal Class II relationships have previously been positively associated with increased treatment time.[22, 34, 37, 47] The study that did not find a significant correlation between overjet and treatment duration included Class I patients.[9] An increasing Class II molar relationship might be expected to extend treatment because of the additional time it will take to correct the Class II, the additional compliance that is required, and the potential need for treatment modalities that increase treatment time, such as extractions or Herbst appliances. In the present study, the Herbst appliance was prescribed more often (77.9%) for patients with excessive overjet than those with normal overjet (59.7%), and also had the longest treatment duration of the treatment modalities. A future study with precise overjet measurements would be beneficial in clarifying its association with treatment duration.

Protrusive incisors also contribute to treatment difficulty. U1-SN was one of the few cephalometric factors in the present study correlated with treatment duration. Protrusive upper incisors adding 4.9 months to treatment time. Lower incisors that were excessively proclined (IMPA>105°) also added significant time to treatment (4.2 months). Protrusive incisors have been previously linked to increased treatment difficulty.[34, 46] The association of increased upper incisor protrusion and excessive overjet may explain why upper incisor protrusion requires more time. While most indices do not allot points for upper incisor proclination, the ABO Discrepancy Index does when the IMPA exceeds 100°.[26, 28, 85]

Even though upper incisor protrusion was more closely associated with treatment difficulty than lower incisor protrusion, practitioners perceive that lower incisor protrusion is more difficult to treat. In the present study, practitioners perceived protrusive upper incisors as the easiest individual factor to treat. Because Class II mechanics involve flaring of the lower incisors, practitioners may think that protrusive lower incisors will necessitate a more difficult treatment plan. Upper incisor retroclination, however, is another side effect of Class II mechanics that is desirable in patients with protrusive upper incisors.[86] Thus, the favorable effects of Class II mechanics on upper, but not lower, incisor proclination may play a role in orthodontists' perceptions of incisor protrusion in Class II patients.

There is no association between crowding and treatment difficulty. In the first section of the survey, crowding cases were considered to be moderately difficult. There was also no significant difference in treatment time when patients with severe upper or lower crowding were compared to those with minimal to no crowding, and no correlation between treatment duration and crowding in either arch. Some studies have demonstrated low associations between the severity of crowding and treatment duration,[22, 34] and one study showed no association.[43] While crowding may be expected to increase treatment time due to the time needed to align the teeth, the relation may be weaker than expected because the sequence of archwires generally remains the same, independent of the presence of crowding. Also, severe crowding may take less time to treat when performing extractions due to minimal space to close once alignment is complete. In addition, the time needed for Class II correction may render the time needed for alignment insignificant.

An excessively high ANB positively affects treatment duration. In the current study, the ANB angle showed a significant difference in treatment time between groups

(3.3 months) when the cutoff point was set to 7°, even though it was not correlated with treatment duration otherwise. A consistent correlation has been reported between ANB and treatment time.[11, 34, 46, 47] ANB may be linked to increased treatment time due to its close association with Class II molar relationships, which have been definitively linked to increased treatment duration in the literature.[13, 37, 87] In the current study, all patients were treated with Class II mechanics regardless of ANB, potentially diminishing the effect of ANB on treatment duration.

Sex is significantly related to treatment duration. In private practice sample, males took 3.6 months longer to treat than females. Two studies have reported no difference in treatment duration between sexes,[9, 88] and one reported that males took 1.2 months longer to treat than females.[47] This could be due to better compliances reported in females than males.[89-91] In addition, there could be hormonal differences between the sexes that contribute to faster tooth movement in females.[92]

Older children have shorter treatment durations than younger children. Patient start age was negatively correlated with treatment duration, indicating that an older child takes less time to treat than a younger child. Two studies have found no relationship between treatment start age and treatment duration,[9, 47] and two reported a negative correlation.[37, 88] This could be due to the fact that younger children may not have a fully erupted permanent dentition at the beginning of treatment. Because the present study did not exclude patients who were in the mixed permanent dentition at the start of phase II, it is likely that this is the factor that affected treatment duration.

Cases treated with extractions did not have a longer treatment duration than those treated non-extraction. Overall, extraction cases took 2.1 months longer to treat that non-extraction cases, but this difference was not significant. The literature reports that extraction treatment takes 2.6-6 months longer than non-extraction treatment.[11, 22, 47, 88, 93, 41] This discrepancy can be explained by the Class II patients used in this study. For them, even a non-extraction plan would extend their treatment due to the need for compliance or a Class II-correcting appliance.[37] Class II patients treated with extractions may require less compliance, thereby leveling out the differences in treatment duration.

Treatment with a Herbst appliance take significantly longer than treatments with Class II elastics or Forsus appliances. In the present study, the Herbst group took 6.9 months longer to treat than the elastics/Forsus group. Differences of 6.9-8.4 months have been previously reported.[33, 37] Treatment with a Herbst may have required additional time because these patients had significantly more severe Class II molar relationships than the elastics/Forsus group patients ($p<0.001$). In addition, the Herbst appliance typically involves a year or more of initial treatment for Class II correction prior to full bonding, whereas other forms of Class II correction can occur concomitant with leveling and alignment of the teeth.

Interestingly, the treatment modality had less of an effect on treatment duration in patients with excessive overjet. When patients with excessive overjet were treated with elastics, a Forsus, or extractions, they required 4.4-4.8 months longer to treat than patients with normal overjet. This could be explained by the fact that patients with excessive overjet had a significantly more severe Class II molar relationship than those with normal overjet (p<0.001). In plans with extractions or elastics, there may be an increased need for anchorage or compliance in patients with excessive overjet or a more severe Class II molar relationship, both of which have been shown to increase treatment duration.[90, 91, 94-97] The Herbst appliance took the same amount of time in both normal and excessive overjet patients. Herbst treatment duration was likely the same because increasing amounts of overjet require increased appliance activation, rather than an increased time in the appliance.

This study is not without limitations. While the original intent of the study was to identify patients who exhibited all of the Moyer's facial types, there were not enough patients who fit these facial types in the present study. For example, there were relatively few open bite patients. Although the proportion of open bite cases in this study (2.8%) was similar to the prevalence of open bite in the United States (2.9%),[98] a study with a larger overall sample would be necessary to elucidate the effect of open bites on treatment duration. In addition, it was difficult to accurately determine the contributions of the individual factors to facial type difficulty because confounding variables could not be eliminated. Finally, overjet, overbite, and crowding were derived from photographs and not measured. A more objective assessment of these factors would be beneficial in creating a future difficulty index.

This study has implications on the future creation of a difficulty index. First, within the private practice studied, cephalometric analyses were primarily indicative of treatment duration because of their correlation with dental malocclusions such as Class II molar relationship and overjet. When a multiple regression analysis was performed with all patient variables, only U1-SN was included as a predictor of treatment duration. U1-SN was positively correlated with treatment duration, and an excessive IMPA and ANB also added to treatment time. These factors may contribute to treatment duration in a discriminate function fashion. Dental malocclusion, however, was distinctly correlated to treatment duration. Of all variables investigated, overbite, overjet, molar sum, U1-SN sex, and treatment start age explained 23.3% of treatment variability, with overbite being the primary predictor, while overjet, overbite, and molar sum alone explained 20.1% of this variation. In addition, dental overbite was the most contributory factor to orthodontist perception of treatment difficulty. Because of the predictive weight of the dental malocclusion, a study comparing treatment duration with both cephalometric tracings and precise measurements of dental casts is necessary to create a helpful difficulty index.

CHAPTER V

CONCLUSIONS

1. ABO-certification and experience in practice are significantly correlated with the perception of treatment difficulty.
2. Open bite is perceived as the most difficult factor to treat individually and is the most important predictor of increased treatment duration, while deep bites contribute moderately.
3. Excessive overjet and increasing Class II molar severity are both predictive of increased treatment duration.
4. Protrusive lower incisors are perceived as difficult to treat, though upper incisor proclination is more closely associated with treatment duration.
5. There is no association between crowding and treatment duration in Class II patients.
6. Although facial types with hyperdivergence are perceived as difficult to treat by orthodontists, mandibular plane angle is not related to treatment duration.
7. Females and older children have significantly shorter treatment durations than males and younger children.
8. Treatment plans involving the Herbst appliance take longer than extraction plans and longer still than plans with elastics or the Forsus appliance.

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APPENDIX A

FIGURES

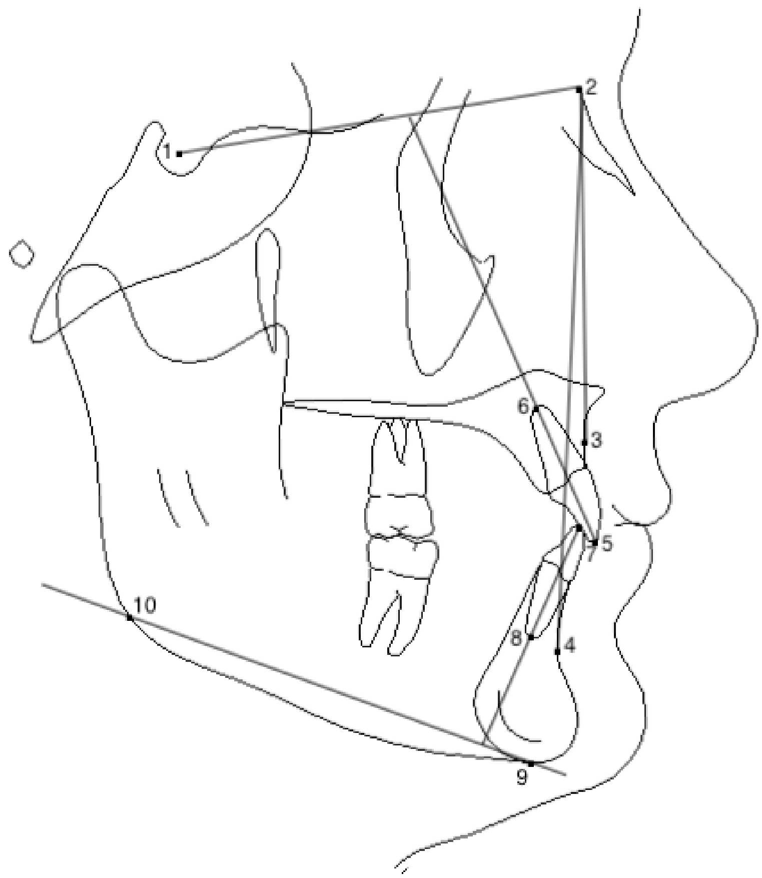

Figure 1. Cephalometric Points digitized for the cephalometric analysis conducted on cases from the three privates: (1) Sella, (2) Nasion, (3) A-point, (4) B-point, (5) Upper Incisor Edge, (6) Upper Incisor Apex, (7) Lower Incisor Edge, (8) Lower Incisor Apex, (9) Menton, (10) Gonion

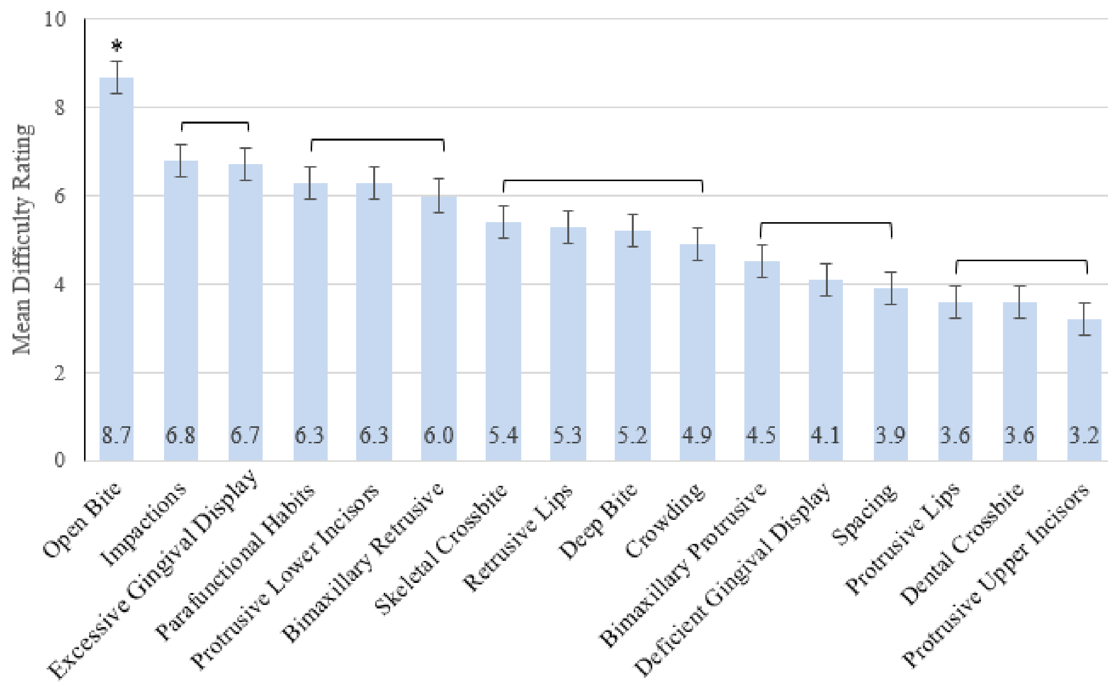

Figure 2. Mean difficulty ratings for individual factors, with asterisk and bars indicating tiers of difficult between which there were statistically significant (p<0.05) differences.

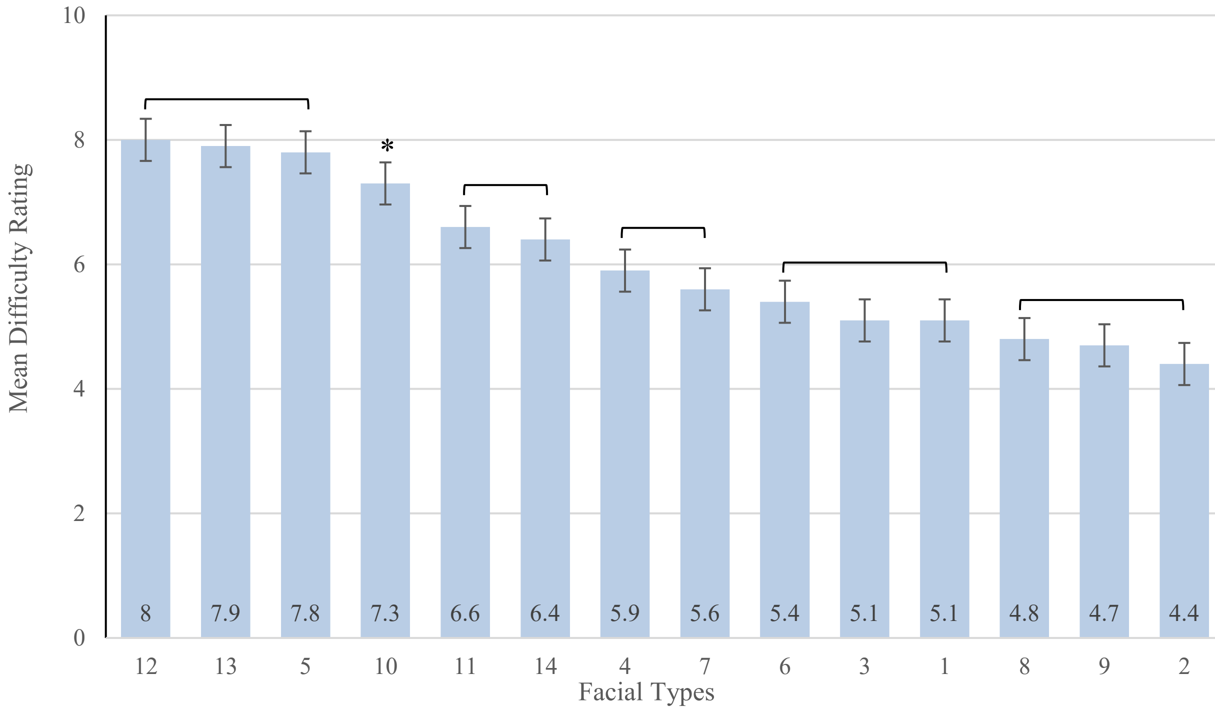

Figure 3. Mean difficulty ratings for facial types with asterisk and bars indicating tiers of difficulty between which there were statistically significant (p<0.05) differences.

Figure 4. Survey

The Difficulty of Treating Class II Malocclusions

Texas A&M College of Dentistry Graduate Research Survey

Katherine Skillestad, DDS

Thank you for agreeing to complete this survey! Our goal is to determine the factors that increase the difficulty of orthodontic treatment.

For this particular study, we have narrowed our focus on **Class II** dental malocclusions, which may or may not be accompanied by a similar skeletal discrepancy.

Please think of **difficulty** in terms of treatment duration and/or chairside time, or the amount of doctor time needed. A simple way to think about this is to imagine to what extent these factors would cause you to increase a patient's estimated treatment time.

How do the listed factors contribute to the difficulty of treating a Class II Molar case non-surgically?

Please circle an integer from 1-10. A score of "0" indicates no effect on the difficulty of the case, and a score of "10" indicates a large effect on difficulty.

	No effect					Effect on Difficulty					Large effect
Open Bite	0	1	2	3	4	5	6	7	8	9	10
Deep Bite	0	1	2	3	4	5	6	7	8	9	10
Severe Crowding	0	1	2	3	4	5	6	7	8	9	10
Severe Spacing	0	1	2	3	4	5	6	7	8	9	10
Protrusive Lips	0	1	2	3	4	5	6	7	8	9	10
Retrusive Lips	0	1	2	3	4	5	6	7	8	9	10
Excess Gingival Display	0	1	2	3	4	5	6	7	8	9	10
Deficient Gingival Display	0	1	2	3	4	5	6	7	8	9	10
Proclined Upper Incisors	0	1	2	3	4	5	6	7	8	9	10
Proclined Lower Incisors	0	1	2	3	4	5	6	7	8	9	10
Bimaxillary Protrusive	0	1	2	3	4	5	6	7	8	9	10
Bimaxillary Retrusive	0	1	2	3	4	5	6	7	8	9	10
Dental Crossbite	0	1	2	3	4	5	6	7	8	9	10
Skeletal Crossbite	0	1	2	3	4	5	6	7	8	9	10
Habits (tongue, finger, etc.)	0	1	2	3	4	5	6	7	8	9	10
Impacted Teeth	0	1	2	3	4	5	6	7	8	9	10

For each of the following scenarios, rate the difficulty of treating a patient with the listed characteristics, with "0" indicating a patient that is very simple to treat, and "10" indicating a patient that is very difficult to treat.

Note: While a graphic representation of the written data is included, please refer to the text primarily when making decisions about case difficulty. Each diagnosis written is definitive.

Remember:
1. This survey refers only to **Class II molar/canine growing** patients treated **non-surgically**. Assume at least an **end-on** molar relationship.
2. **Difficulty** refers to treatment duration and/or chairside time, or the amount of doctor-time needed.

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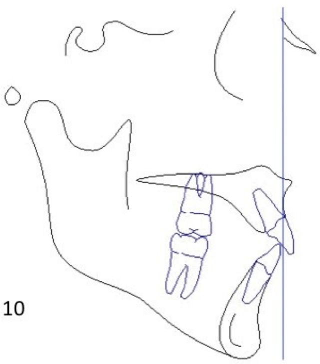
1)



Jaws:	Skeletal Class II		
Maxilla:	Normal	**Upper Incisors:**	Normal
Mandible:	Retrusive	**Lower Incisor:**	Normal
Vertical:	Hyperdivergent		

0 1 2 3 4 5 6 7 8 9 10

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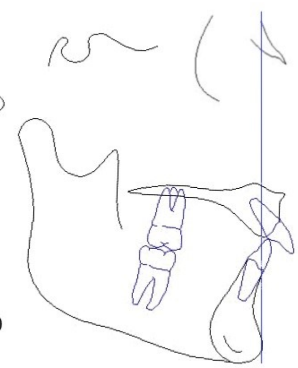
2)



Jaws:	Skeletal Class II		
Maxilla:	Protrusive	**Upper Incisors:**	Protrusive
Mandible:	Normal	**Lower Incisor:**	Normal
Vertical:	Hypodivergent, Deep Bite		

0 1 2 3 4 5 6 7 8 9 10

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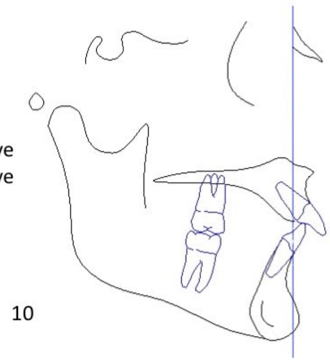
3)

Jaws: Skeletal Class II
Maxilla: Protrusive **Upper Incisors:** Protrusive
Mandible: Normal **Lower Incisor:** Protrusive
Vertical: Normodivergent, Deep Bite

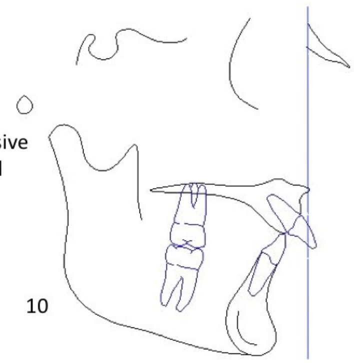
0 1 2 3 4 5 6 7 8 9 10



4)

Jaws: Skeletal Class II
Maxilla: Retrusive **Upper Incisors:** Protrusive
Mandible: Retrusive **Lower Incisor:** Normal
Vertical: Hypodivergent, Deep Bite

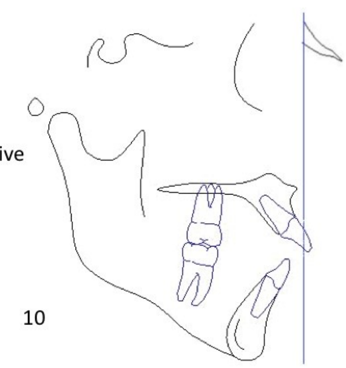
0 1 2 3 4 5 6 7 8 9 10



5)

Jaws: Skeletal Class II
Maxilla: Retrusive **Upper Incisors:** Protrusive
Mandible: Retrusive **Lower Incisor:** Normal
Vertical: Hyperdivergent, Open Bite

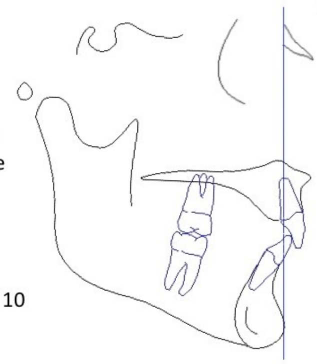
0 1 2 3 4 5 6 7 8 9 10



6)

Jaws: Skeletal Class II
Maxilla: Protrusive **Upper Incisors:** Retrusive
Mandible: Normal **Lower Incisor:** Protrusive
Vertical: Normodivergent, Deep Bite

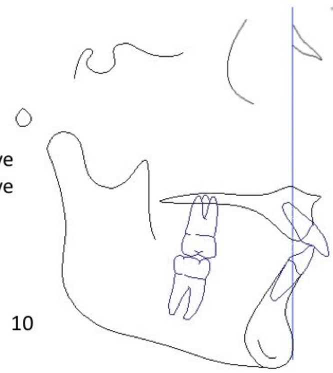
0 1 2 3 4 5 6 7 8 9 10



7)

Jaws: Skeletal Class II
Maxilla: Protrusive **Upper Incisors:** Protrusive
Mandible: Normal **Lower Incisor:** Protrusive
Vertical: Hypodivergent, Deep Bite

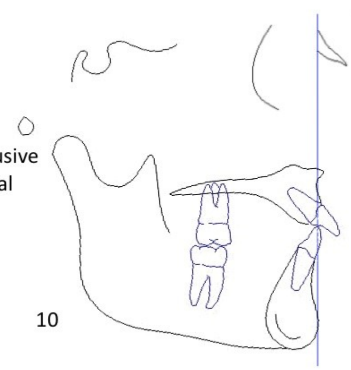
0 1 2 3 4 5 6 7 8 9 10



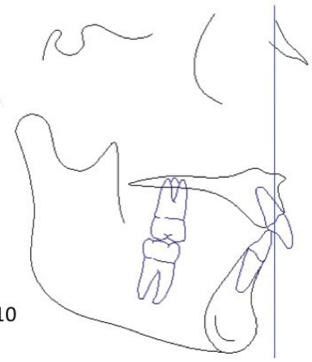
8)

Jaws: Skeletal Class I
Maxilla: Normal **Upper Incisors:** Protrusive
Mandible: Normal **Lower Incisor:** Normal
Vertical: Hypodivergent, Deep Bite

0 1 2 3 4 5 6 7 8 9 10



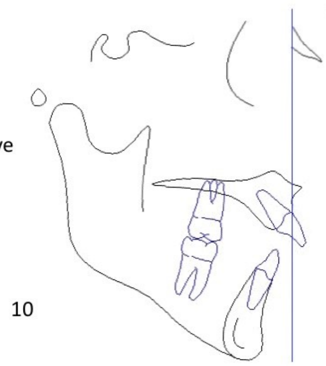
9)



Jaws: Skeletal Class II
Maxilla: Normal **Upper Incisors:** Normal
Mandible: Retrusive **Lower Incisor:** Normal
Vertical: Hypodivergent, Deep Bite

0 1 2 3 4 5 6 7 8 9 10

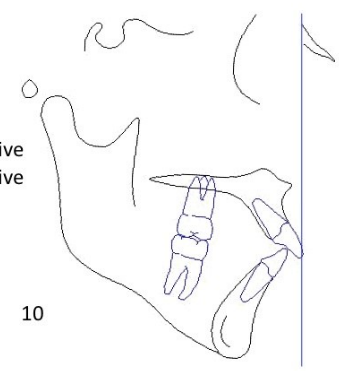
10)



Jaws: Skeletal Class II
Maxilla: Normal **Upper Incisors:** Protrusive
Mandible: Retrusive **Lower Incisor:** Upright
Vertical: Hyperdivergent, Open Bite

0 1 2 3 4 5 6 7 8 9 10

11)

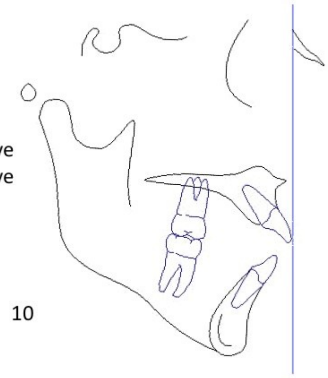


Jaws: Skeletal Class II
Maxilla: Retrusive **Upper Incisors:** Protrusive
Mandible: Retrusive **Lower Incisor:** Protrusive
Vertical: Hyperdivergent

78

0 1 2 3 4 5 6 7 8 9 10

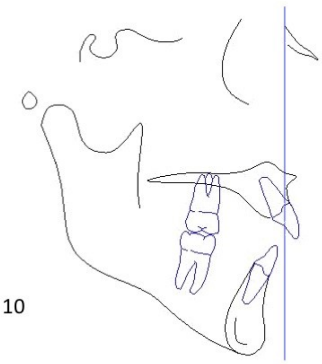
12)



Jaws:	Skeletal Class II		
Maxilla:	Retrusive	**Upper Incisors:**	Protrusive
Mandible:	Retrusive	**Lower Incisor:**	Protrusive
Vertical:	Hyperdivergent, Open Bite		

0 1 2 3 4 5 6 7 8 9 10

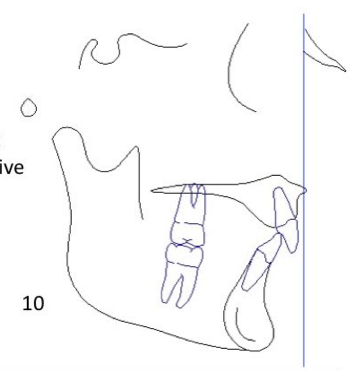
13)



Jaws:	Skeletal Class II		
Maxilla:	Normal	**Upper Incisors:**	Normal
Mandible:	Retrusive	**Lower Incisor:**	Normal
Vertical:	Hyperdivergent, Open Bite		

0 1 2 3 4 5 6 7 8 9 10

14)



Jaws:	Skeletal Class II		
Maxilla:	Retrusive	**Upper Incisors:**	Upright
Mandible:	Retrusive	**Lower Incisor:**	Protrusive
Vertical:	Hypodivergent, Deep Bite		

0 1 2 3 4 5 6 7 8 9 10

Demographics—*this data is important in discerning if the population sample is reflective of the orthodontists in the United States*.

Years in practice: _________

Sex: M F Prefer not to answer

Are you Board-Certified by the American Board of Orthodontics? Y N

Thank you for your input!

APPENDIX B

TABLES

Table 1. Scoring method for molar relationship in private practice study patients.

Classification	Score	Description
Class I	0	The mesiobuccal cusp of the upper first molar is aligned with the central groove of the lower first molar.
Class II ¼-step	1	The mesiobuccal cusp of the upper first molar is between the central groove and the buccal cusp tip of the mandibular first molar.
Class II ½-step	2	The mesiobuccal cusp of the upper first molar aligns with the buccal cusp tip of the mandibular first molar.
Class II ¾-step	3	The mesiobuccal cusp of the upper first molar is between the buccal cusp tip of the mandibular first molar and the mandibular first molar and mandibular second premolar embrasure.
Class II full-step	4	The mesiobuccal cusp of the upper first molar is aligned with or beyond the mandibular first molar and mandibular second premolar embrasure

Table 2. Survey facial type descriptions.

	Skeletal Pattern	Maxilla	Mandible	MPA	Overbite	Upper Incisors	Lower incisors
1	Class II	Normal	Retrusive	Hyper	Normal	Normal	Normal
2	Class II	Protrusive	Normal	Hypo	Deep	Protrusive	Normal
3	Class II	Protrusive	Normal	Normal	Deep	Protrusive	Protrusive
4	Class II	Retrusive	Retrusive	Hypo	Deep	Protrusive	Normal
5	Class II	Retrusive	Retrusive	Hyper	Open	Protrusive	Normal
6	Class II	Protrusive	Normal	Normal	Deep	Retrusive	Protrusive
7	Class II	Protrusive	Normal	Hypo	Deep	Protrusive	Protrusive
8	Class I	Normal	Normal	Hypo	Deep	Protrusive	Normal
9	Class II	Normal	Retrusive	Hypo	Deep	Normal	Normal
10	Class II	Normal	Normal	Hyper	Open	Protrusive	Retrusive
11	Class II	Retrusive	Retrusive	Hyper	Normal	Protrusive	Protrusive
12	Class II	Retrusive	Retrusive	Hyper	Open	Protrusive	Protrusive
13	Class II	Normal	Retrusive	Hyper	Open	Normal	Normal
14	Class II	Retrusive	Retrusive	Hypo	Deep	Retrusive	Protrusive

Table 3. Kruskal-Wallis one-way ANOVA analysis of difficulty from facial types.

	Number of associated facial types		Difficulty (0-10) Mean	SD	Group differences *p-value*	Post-hoc Bonferroni test p<0.05
MPA	5	**Hyper**[a]	**7.2**	1.2	<0.001	a>b,c
	2	Normal[b]	5.3	1.5		
	7	Hypo[c]	5.3	1.4		
AP Mandible	6	**Retrusive**[a]	**6.6**	1.0	0.004	a>b
	8	Normal[b]	5.5	1.3		
AP Maxilla	5	**Retrusive**[a]	**7.0**	1.2	0.003	a>b>c
	5	Normal[b]	6.0	1.2		
	4	Protrusive[c]	5.1	1.4		
Jaw Relationship	1	**Class II**[a]	**6.2**	1.0	<0.001	a>b
	13	Class I[b]	4.8	1.8		
Overbite	8	**Open**[a]	**7.8**	1.4	<0.001	a>b>c
	2	Normal[b]	5.8	1.4		
	4	Deep[c]	5.3	1.3		
U1 Inclination	2	**Protrusive**[a]	**6.2**	1.2	0.04	a>b,c
	3	Normal[b]	5.9	1.1		
	9	Retrusive[c]	5.8	1.5		
L1 Inclination	1	**Retrusive**[a]	**7.3**	1.9	<0.001	a>b>c
	7	Protrusive[c]	6.2	1.2		
	6	Normal[b]	5.8	1.1		

Table 4. One-way ANOVA analysis of between-practice differences in pre-treatment continuous variables.

	Overall (n=211)		Practice A (n=92)		Practice B (n=69)		Practice C (n=50)		Group Differences	Post-hoc Bonferroni test
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p-value*	(p<0.05)**
Tx Start Age	12.5	1.0	12.7	1.0	12.4	1.0	12.4	1.1	0.234	--
Tx Duration (months)	30	7.8	31.2	7.8	31.2	7.8	27.6	8.4	0.039	A,B>C
Emrgs	2.3	2.0	1.7	1.7	3.3	2.3	1.9	1.8	<0.001	B>A,C
SNA	81.5	3.8	81.9	3.6	81.1	3.9	81.2	4.1	0.377	--
SNB	76.3	3.6	77.0	3.2	75.6	3.4	76.2	4.1	0.038	A>B
ANB	5.2	2.3	4.9	1.9	5.6	2.5	5.1	2.5	0.212	--
U1-SN	104.0	9.9	104.9	10.1	102.3	10.7	104.8	8.3	0.195	--
IMPA	96.7	6.8	98.5	6.9	94.0	6.7	97.2	5.4	<0.001	A,C>B
MPA	32.6	5.7	31.8	5.6	33.5	5.8	33.0	5.5	0.153	--
Molar Class II*	4.9	1.9	5.0	1.8	5.4	1.9	4.0	1.6	<0.001	A,B>C

*Average combined molar sum (Table 7), **"A" indicates practice A, "B" indicates practice B, and "C" indicates practice C

Table 5. Chi square analyses of between-practice differences in pre-treatment variables.

		Overall n=211 %	Prac. A n=92 %	Prac, B n=69 %	Prac. C n=50 %	Chi Square Test *p-value*	Post-hoc Bon. test p<0.05
Sex	Male	47.9	54.3	43.5	42.0	0.307	--
	Female	52.1	45.7	56.5	58.0		--
Overbite	Deep Bite	56.9	68.5	59.4	32.0	<0.001	A,B>C
	Normal	40.3	29.3	36.2	66.0		C>A,B
	Open Bite	2.8	2.2	4.3	2		--
Overjet	Normal	63.5	67.4	50.7	74.0	0.009	C>A>B
	Moderate	26.1	26.1	29.0	22.0		--
	Severe	10.4	6.5	20.3	34.0		B>A,C
Upper TSALD	Normal[†]	23.7	17.4	18.8	42.0	<0.001	C>A,B
	Moderate	46.0	51.1	46.4	36.0		A,B>C
	Severe	30.3	31.5	34.8	22.0		A,B>C
Lower TSALD	Normal[†]	15.6	3.3	17.4	36.0	<0.001	C>B>A
	Moderate	64.9	79.3	56.5	50.0		A>B,C
	Severe	19.4	17.4	26.1	14.0		--
Tx Type	Elastics	19.8	10.9	33.3	18.0	<0.001	B>C>A
	Forsus	9.0	1.1	0	36.0		C>A,B
	Herbst	38.7	39.1	40.6	36.0		--
	Ext (1*)	0.9	1.1	1.4	0		--
	Ext (2)	18.9	37.0	8.7	0		A>B,C
	Ext (3)	0.5	1.1	0	0		--
	Ext (4)	7.1	7.6	11.6	0		B>A>C
	Distalizatio n	4.2	0	1.4	0		--
	Headgear	0.5	2.2	2.9	10		--

[†]Normal TSALD includes spacing, no crowding, and mild crowding, *Indicates the number of premolar extractions, **In this column, A indicates practice A, B indicates practice B, and C indicates practice C.

Table 6. Independent t-tests relating treatment duration to treatment variables

		Treatment duration (months)			Treatment duration (months)		Significant differences (months)	*p-value*
		Mean	SD		Mean	SD		
ANB (°)	Class I (<4°)	30.0	7.7	Class II (≥4°)	30.6	7.7	--	0.619
	Mild Class II (<7°)	29.7	7.4	Severe Class II (>7°)	33.0	8.2	3.3	0.013
SNA (°)	Normal (78°-85°)	30.5	7.4	Protrusive (>85°)	31.0	8.7	--	0.747
	Normal (78°-85°)	30.5	7.4	Retrusive (<78°)	28.9	7.9	--	0.287
SNB (°)	Normal (≥78°)	30.3	7.7	Retrusive (<78°)	30.4	7.7	--	0.890
U1-SN (°)	Normal (100°-110°)	28.6	7.2	Protrusive (>110°)	33.5	7.9	4.9	<0.001
	Normal (100°-110°)	28.6	7.2	Retrusive (<100°)	30.1	7.3	--	0.059
IMPA (°)	Normal (<100°)	30.1	7.6	Protrusive (≥100°)	31.0	7.8	--	0.423
	Protrusive (<105°)	29.9	7.5	Protrusive (≥105°)	34.1	8.2	4.2	0.010
MPA (°)	Normal (28°-38°)	30.9	7.5	Hypodivergent (<28°)	30.1	7.2	--	0.552
	Normal (28°-38°)	30.9	7.5	Hyperdivergent (>38°)	28.5	8.6	--	0.094
Overbite	Normal	27.8	7.9	Open	37.0	8.0	9.2	0.007
	Normal	27.8	7.9	Deep	31.9	6.9	4.1	<0.001
Overjet	Normal*	28.8	7.6	Excessive**	33.1	7.1	4.3	<0.001
Sex	Female	28.6	7.7	Male	32.2	7.3	3.6	0.001

Table 7. One-way ANOVA analysis of treatment duration differences based on treatment modality and overjet, with normal to mild overjet categorized as normal, and moderate to severe overjet categorized as excessive.

	Mean treatment duration ± SD (months)			Group differences	Post-hoc Bonferroni Test (p<0.05)
	Elastics/ Forsus (n=64)	Herbst (n=83)	1-4 Extractions (n=64)	*p-value*	
Overall	26.8 ± 8.4[a]	33.7 ± 6.5[b]	29.5 ± 6.8[c]	<0.001	b>a, c
Normal Overjet	25.8 ± 8.3[a]	33.0 ± 6.3[b]	28.0 ± 6.0[c]	<0.001	b>a, c
Excessive Overjet	30.6 ± 7.2[a]	34.4 ± 7.2[b]	32.4 ± 7.2[c]	0.213	--

Table 8. Pearson correlations between continuous pre-treatment variables and treatment durations.

	Correlation	*p-value*
Start Age	-0.174	0.011
SNA	0.046	0.510
SNB	-0.017	0.802
ANB	0.106	0.126
U1-SN	0.148	0.031
IMPA	0.052	0.451
MPA	-0.060	0.382
UTSALD	-0.105	0.129
LTSALD	0.013	0.851
Molar sum	0.271	<0.001